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The Practical Teaching Reform of the "Principles of Automatic Control" Course Based on Simulink in MATLAB

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Abstract: In the teaching process of "Principles of Automatic Control", the block diagrams of control systems are rather abstract, and their alignment with the specific implementations in practical application scenarios still needs to be improved. If only the illustrations in traditional textbooks or online floor plans combined with oral descriptions are used for explanation, students will find it difficult to connect them with practical application scenarios. This paper first analyzes the reasons why the theory of automatic control principles and practical teaching are prone to disconnection. Secondly, it uses the Simulink sub-module of the simulation software MATLAB to simulate and reproduce the complex control system in this course. Finally, it quantitatively analyzes the typical control indicators in the control system through this simulation model. The steady-state and dynamic characteristics of the control system are vividly and intuitively demonstrated by observing the input and output quantities of typical links, and this achievement is further applied to actual teaching.

1. Introduction

With the widespread integration of computers and multimedia technology into modern educational practice, profound and far-reaching transformations are being introduced into conventional instructional methodologies. While traditional teaching approaches—primarily reliant on blackboard writing and textbook-based explanation—remain foundational in many educational contexts, they are now being progressively supplemented and enriched by advanced digital tools, including multimedia projection systems and specialized simulation software. These technological aids have gradually evlvolved from occasional supplements to integral components of the day-to-day teaching environment, reshaping how knowledge is delivered and comprehended[1-3].

Furthermore, in response to the growing emphasis on aligning pedagogical theory with real-world application, contemporary educators face expanded responsibilities. They are now expected not only to develop well-structured, visually engaging PowerPoint presentations based on curricular content but also to deliver theoretical knowledge in a concrete, relatable, and accessible manner by consistently connecting abstract concepts to practical contexts and industrial applications. This pedagogical shift reflects broader changes in educational philosophy that prioritize competency development and practical problem-solving skills alongsidetable theoretical understanding[4-8].

As a core compulsory subject within the automation discipline, the "Principles of Automatic Control" course presents particular instructional challenges due to its extensive coverage of structural principles, mathematical models, and operational characteristics of various automatic control systems. The subject matter inherently requires visualizing dynamic processes and understanding complex system interactions—elements that traditional teaching methods often struggle to convey effectively. Currently, a noticeable gap persists between theoretical instruction and practical implementation in existing PPT-based teaching resources, limiting the effectiveness of knowledge transfer and leaving students with an incomplete understanding of how theoretical concepts manifest in real engineering contexts[9-10].

Against the backdrop of rapidly advancing computer simulation technology, sophisticated tools such as MATLAB have gained significant prominence across multiple industrial and research sectors—including smart city planning, digital twin applications, robotics, and industrial automation—due to their cost-effectiveness, operational flexibility, modeling accuracy, and ease of use. By enabling detailed modeling, accurate parameter configuration, and dynamic simulation of real-world scenarios, such tools provide a powerful platform for experiential learning that bridges the gap between abstract theory and tangible practice[10-12].

The strategic integration of MATLAB, particularly its specialized Simulink module, into the instructional framework of the "Principles of Automatic Control" course effectively addresses the longstanding issue of disconnection between abstract control theory and engineering practice. Through Simulink's intuitive block diagram interface, educators can construct sophisticated models that simulate the behavior of specific control system components, visualize dynamic processes in real-time, and demonstrate complex system interactions in an intuitive, visually comprehensible manner. This integration not only reinforces the coherence between theoretical principles and practical applications but also unveils the intrinsic mechanisms of control systems in a more vivid and engaging fashion[8-12].

By observing how variations in PID parameters affect system stability, or how different controller configurations influence transient response, students develop a deeper, more intuitive understanding of control principles that transcends purely mathematical treatment. The simulation environment allows for safe experimentation with system configurations that would be impractical or hazardous to implement physically, while providing immediate visual feedback that solidifies conceptual understanding. This hands-on computational approach significantly enhances students' grasp of fundamental concepts, characteristic behaviors, and implementation strategies of typical control systems, thereby elevating the overall learning experience and better preparing them for professional engineering challenges[9-15].

The incorporation of simulation technology also fosters the development of systemic thinking and problem-solving skills, as students learn to approach control systems as integrated wholes rather than collections of isolated components. This pedagogical innovation represents a significant step toward cultivating the next generation of automation engineers who are equally comfortable with theoretical analysis and practical implementation—a crucial balance in an increasingly complex technological landscape.

2. Deficiencies in the Teaching of the "Automatic Control System" course

"Automatic Control System" is an important compulsory professional course for automation and related majors. It is characterized by abstract theory and complex content, and has a large number of students. Over the years, in order to improve teaching quality and enhance students' understanding of the courses, the teaching and research office, with the support and assistance of the school, has carried out a large amount of work around optimizing courseware. However, with the continuous optimization of courseware, the shortcomings of the flat teaching based on courseware and textbooks have gradually emerged, mainly manifested as:

1) As this course requires the explanation of the structure, principles, and related characteristics of a large number of control systems. At present, the explanations based on flat courseware are still rather abstract and have varying degrees of problems in terms of innovation, understandability and practicality.

2) This course is now taught in English. Due to its abstract theory and high difficulty, when providing targeted explanations on the principles, structures, and characteristics of complex control systems, Without the aid of simulation software, it is difficult to understand and it is hard to ensure the efficiency of the class.

3) The subsequent practical experiments of this course design a large number of power electronic converter control system implementations. The implementation of these control systems can lay a solid foundation for students' professional working skills. If the combination of theory and practice is enhanced in this course, it will be of great benefit to future work and study. Due to the fact that planar components are prone to being disconnected from reality, it is temporarily difficult to achieve this original intention.

3. The Role of MATLAB's Simulink in inverter teaching

This project team selects the Simulink sub-module of the simulation software MATLAB to implement the typical control system of this course through simulation. This Chapter takes the inverter control system as an example to discuss the advantages of combining Simulink with the teaching of the "Automatic Control System" course.

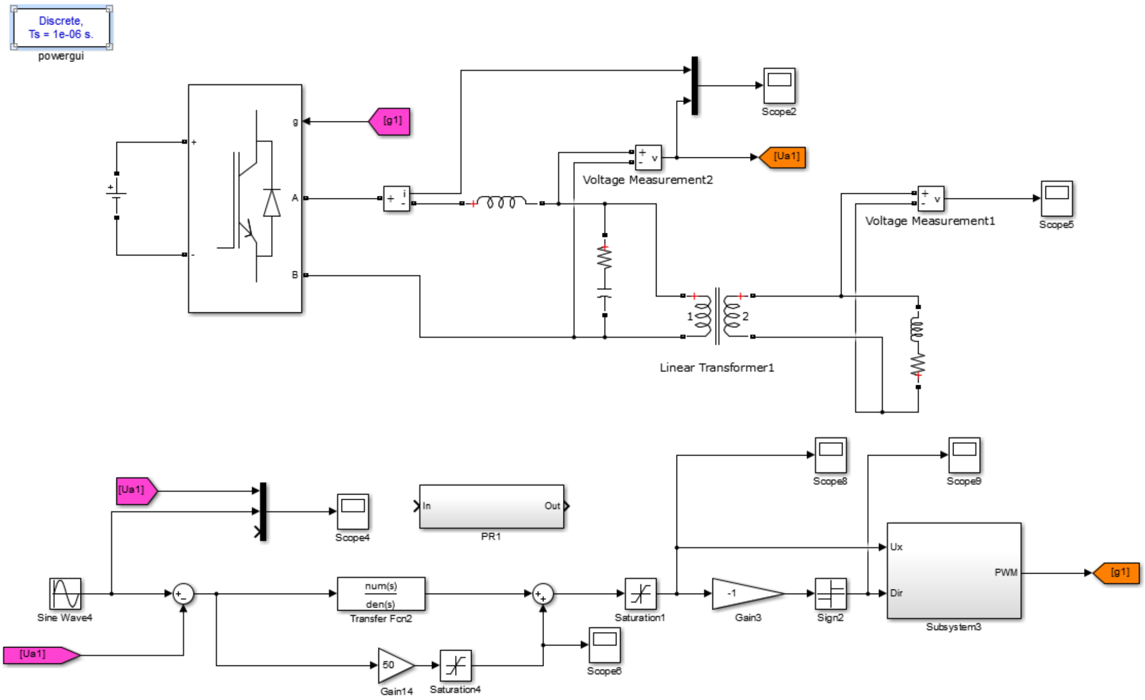
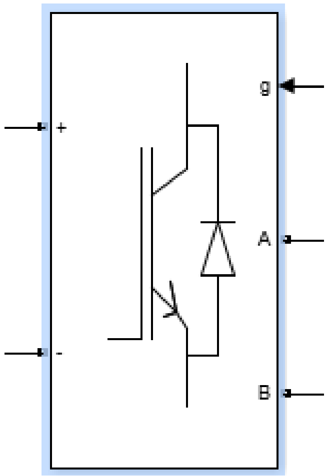
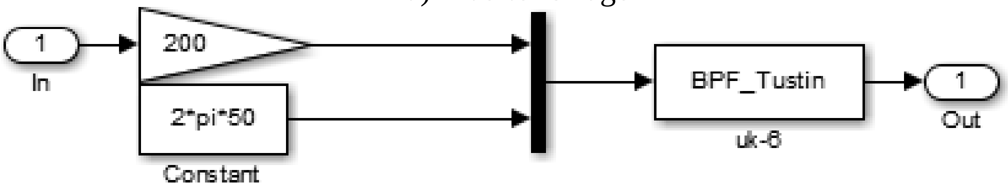


Figure 1 Simulation model of inverter control system based on Simulink



a) Inverter bridge



b) Controller

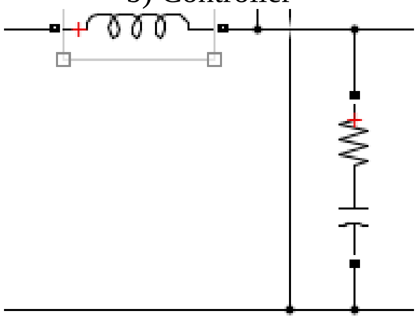
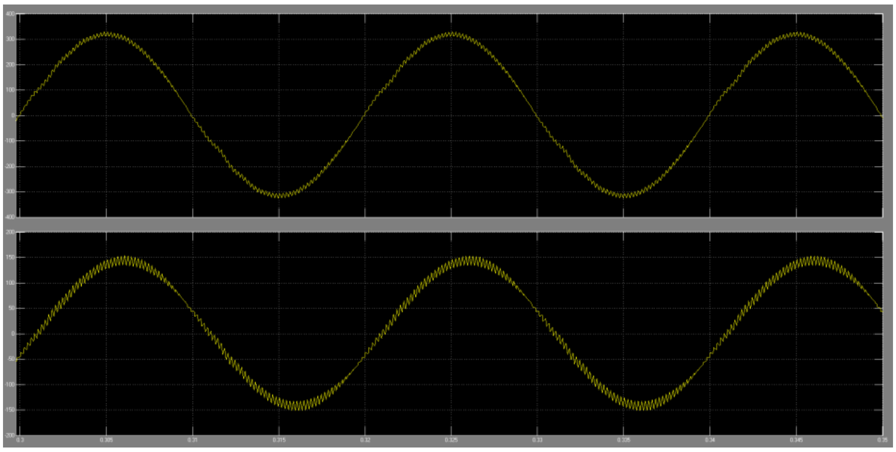

c) Passive filter

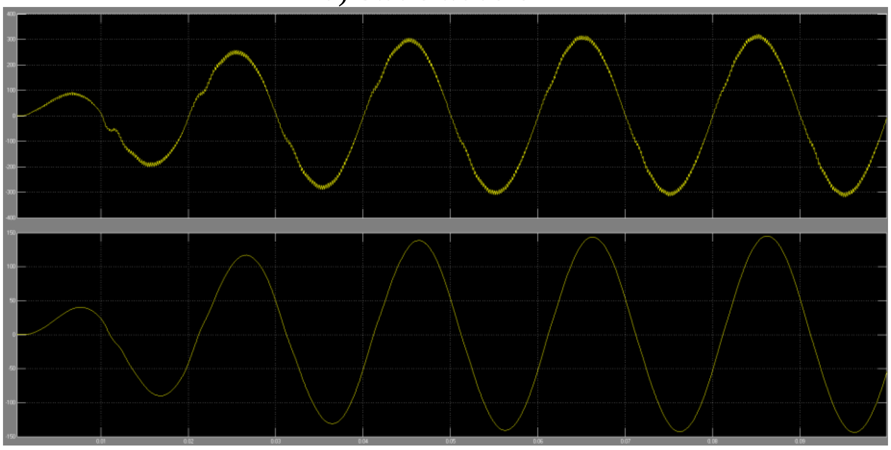
Figure 2 Display diagrams of each control module in the inverter control system

Figure 1 shows the simulation model of the inverter control system made by applying Simulink, and Figure 2 is a separate display diagram of the inverter bridge, controller and passive filter of the inverter control system. Among them, the parameters of each link are designed independently. Students can understand the principle of the inverter control system from different perspectives. Combined with the simulation results, they can further understand the steady-state and dynamic characteristics of the control system, enabling students to have a more multi-angle and three-dimensional understanding of the control system. Moreover, this novel method is more easily accepted by students and can be easily extended to the study of other related fields.

Figure 3 shows the output voltage and current waveforms of the inverter control system. In the Simulink software, the specific demonstrations of steady-state and dynamic waveforms in the inverter control system can be completed. Moreover, during this process, the waveforms can be arbitrarily scaled, achieving an organic unity from macroscopic to microscopic levels. This is of great help for students to understand the structure, principle and implementation of the inverter control system. Moreover, the process of stabilizing parameters and debugging is strictly carried out in accordance with the debugging process of the actual system. This will bring great assistance to students' future course design and work.



a) Static waveform



b) Dynamic waveform

Figure 3 The inverter control system outputs voltage and current waveforms

4. The Role of MATLAB's Simulink in Sliding mode control teaching

This Chapter takes the sliding mode control system as an example to discuss the advantages of combining Simulink with the teaching of the "Automatic Control System"course.

Figure 4 presents a simulation model of a sliding mode control system developed using Simulink, where each component's parameters are independently configurable. This design enables students to comprehend the principles of sliding mode control from multiple perspectives. By analyzing the simulation results, students can further investigate the relationships between control inputs, outputs, and typical state variables, thereby facilitating a comprehensive and multi-dimensional understanding of sliding mode control systems. This innovative pedagogical approach demonstrates higher student acceptance and can be readily extended to the study of other related control methodologies.

Figure 5 displays the waveforms of output, error, and control input in the sliding mode control system. The Simulink environment enables detailed demonstration of both steady-state and transient characteristics inherent to sliding mode control systems. During the simulation process, arbitrary zooming functionality for waveform analysis is supported, achieving an organic integration of macroscopic and microscopic examination. This capability significantly enhances students' comprehension of the system's structure, operational principles, and implementation mechanisms. Furthermore, the parameter tuning process strictly adheres to actual engineering debugging procedures, providing substantial benefits for students' subsequent course projects and future professional practice.

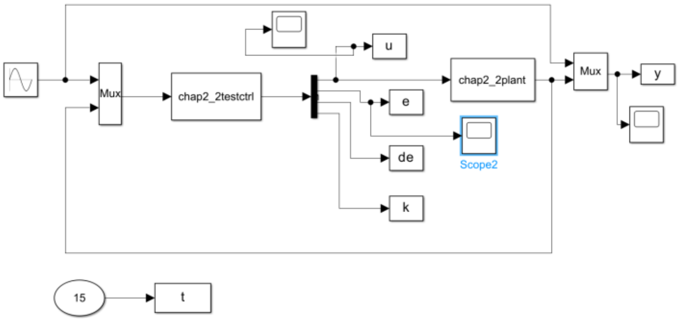
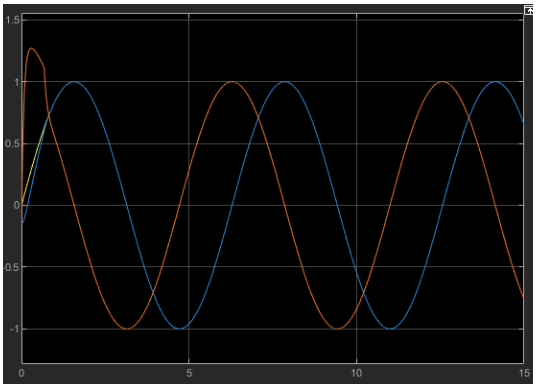
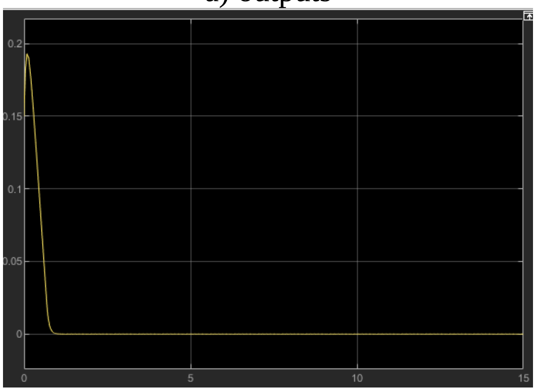


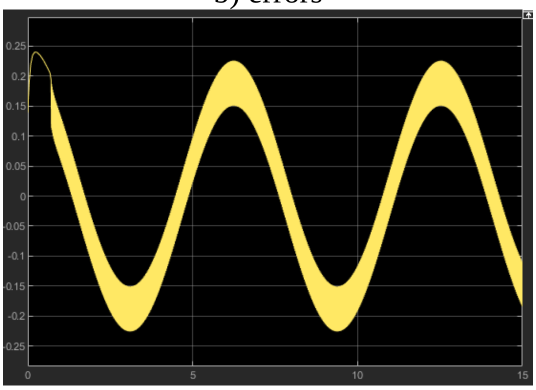
Figure 4 Simulation model of Sliding mode control system based on Simulink



a) outputs



b) errors



c) control input

Figure 5 The sliding mode control system outputs, errors and control input

5. Conclusion

This project uses Simulink in the simulation software MATLAB to reproduce the typical control systems of this course through simulation. Make the teaching courseware more novel, understandable and easy to connect with practical application scenarios. And it can significantly enhance students' enthusiasm for learning. A considerable portion of the research and development achievements of the courseware in this project can be transplanted to the construction of courseware for other courses. It has certain reference significance for the construction of three-dimensional courseware for other courses that combines theory with practice, and it has good compatibility, scalability and broad application prospects. However, in the actual application process, some problems still cannot be avoided. For instance, the simulation effect of many analog control chips in Simulink still needs to be improved and further refined to better apply them in teaching.

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